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APOLLO MISSION TECHNIQUES
C-PRIME LUNAR (ALTERNATE 1)
LUNAR ORBIT ACTIVITIES

TECHNIQUES DESCRIPTION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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APOLLO SPACECRAFT PROGRAM OFFICE
MANNED SPACECRAFT CENTER
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FOREWORD

The Lunar Orbit Activities Mission Techniques Document is one of seven documents describing the C-prime lunar mission. The others are:

- Saturn V/Apollo Launch Aborts
- Earth Parking Orbit and Translunar Injection
- Translunar Midcourse Corrections and Lunar Orbit Insertion
- Transearth Injection, Midcourse Corrections, and Entry
- Tracking Data Selection Controllers Procedures
- Contingency Procedures

The purpose of these documents is to insure compatibility of all related MSC and supporting contractor activities.

For each mission phase, a data priority working group has been established. These groups, which are comprised of representatives of MSC and support contractors, hold frequent meetings to coordinate their various associated activities and develop agreed upon mission techniques. TRW assists in the development of the techniques and documents them for ASPO. After formal review, a document such as this one is issued.

CONTENTS

NOMENCLATURE

AOS	acquisition of signal
CDR	commander (crew)
CMC	command module computer
CMP	command module pilot
DEG	degrees
IMU	inertial measuring unit
LMP	lunar module pilot
LOI-1	lunar orbit insertion burn
LOI-2	lunar orbit circularization burn
LOS	loss of signal
MCC-H	Mission Control Center - Houston
mm	millimeter
MSFN	Manned Space Flight Network
NAV	navigation
Omni	omnidirectional antenna
PAD	data sent to spacecraft over voice link and recorded by crew
rev	revolution
SCS	stabilization and control system
SCT	scanning telescope
SC	spacecraft
SXT	sextant
TBD	to be determined
TEI	transearth insertion
TV	television

NOMENCLATURE (Continued)

P22	Orbit Navigation Program
P27	CMC Update Program
P52	IMU realignment Program

1. INTRODUCTION

This document discusses the activities scheduled to take place during the ten orbits of the nominal C-prime lunar mission. The major activities discussed are:

a) MSFN tracking coverage

b) Navigation sightings

c) IMU alignments

d) Uplinks, downlinks and voice (PAD) data

e) Contingency situations

f) Photographic

g) Television

The primary objectives of the lunar orbit are:

a) Obtain data for postflight analysis to evaluate the errors in MSFN orbit prediction solutions.

b) Obtain data to allow postflight evaluation of the errors in landing site determination.

c) Evaluate the procedures for lunar landmark tracking with respect to vehicle controlability and the ability to visually acquire and mark on landmarks with the sextant.

d) Obtain data for postflight evaluation of the spacecraft Orbit NAV Program (P22).

e) Determine the minimum sun angle at which lunar landmarks can be identified with the clarity required for tracking.

f) Obtain photographs to be used with simulators to provide crew training for subsequent missions.

g) Obtain photos of the lunar far side and eastern limb where previous photos were of poor quality.

2. LUNAR ORBIT ACTIVITIES

2.1 GENERAL

The lunar orbit activities begin after the completion of the LOI-1 burn and terminate with the initiation of the TEI burn. The burn checks for LOI-1, LOI-2, and TEI are similar in nature and are described in References 1 and 2.

The lunar orbit activities are summarized in Figure 1. The orbit counter changes when the spacecraft (SC) passes 180 degrees lunar longitude. The first orbit ends at the 180-degree longitude approximately 2 hours after LOI-1 and is defined as orbit (or revolution) number one. "Morning" and "Evening" terminators are defined as the terminators seen by an observer on the lunar surface, not from the spacecraft. The geometry shown in this figure is for LOI-1 burn at the nominal time launching from earth on December 20 at the first opportunity. The numerous activities referenced to the terminators will change their location in the orbit due to changes in the time of the LOI-1 burn. The lunar orbit activities are discussed in chronological order in the following sections.

2.2 LANDMARK FAMILIARIZATION AND PHOTOGRAPHY

Following LOI-1, the first orbit is primarily an eat period for the crew with television (TV) scheduled to be transmitted to the ground. Revolution (rev) 2 consists of general landmark familiarization, more TV, and preparation for LOI-2. After the postburn checks in rev 3, the SC is maneuvered to photographic attitude and photographs are started for general landmark observation (16 mm) as well as future crew training for landmark identification (Hasselblad). The 16 mm general landmark observation photography is completed in rev 4. Also in rev 4, vertical stereo photography is taken (Hassalblad) by the LMP.

Approximately 30 degrees prior to passing the morning termination on rev 4, the LMP will evaluate the minimum sun angle at which lunar landmarks can be identified with the clarity required for tracking. To accomplish this, the SC will assume a constant acquisition angle of the scanning telescope (SCT) with respect to the local vertical, and then the lunar module pilot (LMP) will verbally describe the terrain as observed through the optics. An attempt may be made by the crew to track a landmark at a sun elevation angle of 3 degrees (Reference 4).

On the earthlit pass of the Fourth revolution the astronaut in the right couch will observe the earthlit surface of the moon to determine whether or not features can be observed in earthshine. If this is feasible, the crew will then track two landmarks on the two successive earthlit revolutions 5 and 6. The same two landmarks will be tracked on both revolutions.

On the dark side, the command module pilot (CMP) will review his maps and prepare for the landmark sightings.

2.3 LANDMARK SIGHTINGS

Revs 5 through 8 are allocated for landmark sightings. The purpose of these sightings is to obtain the data to establish the error uncertainties in lunar landing site determination and to calibrate MSFN. The analysis will be performed postflight. To make the data accessible on the downlink, the sightings will be processed onboard.

The CMP will track a preselected pseudo landing site landmark (a feature with approximately the same terrain and lighting as the lunar landing site). The landing site landmark will have a sun elevation angle of 5 degrees on the fifth orbit. The same pseudo landing site landmark must be tracked on revs 6, 7, and 8. The sun elevation angles for these revs will be 6 degrees, 7 degrees, and 8 degrees, respectively.

In addition to the pseudo landing site landmark, three other landmarks will be tracked as indicated in Figure 1. These landmarks may also be preselected, but the crew may select and track on other landmarks deemed acceptable. If landmarks thus selected are tracked, the crew will identify them on the map aids. It is mandatory that the same four landmarks be tracked for the four-orbit tracking sequence (Reference 4). The priority ranking of the sightings to be taken on the known and unknown landmarks is (see Figure 1):

a) Sightings on the known landmark (psuedo landing site landmark) are priority 1.

b) Sightings just prior to the sub-solar point are priority 2.

c) Sightings nearest the evening terminator are priority 3.

d) Sightings past the sub-solar point are priority 4.

The landmark sightings are performed using P22. The crew will orient the spacecraft pitched up 5 degrees from local horizontal and hold this attitude with fixed optics angle for a landmark acquisition. A 0.3-degree second pitch rate will be performed during the marking process to provide more time for marking. After the sighting sequence (5 marks) the crew will have displayed ΔR and ΔV (the state vector corrections, which will always be 0). The crew must hold at this point in the program for 60 seconds to allow sufficient time for recording (tape) of the mark data at low-bit rate. This procedure is required for the landmarks out of sight of MSFN and will be used for those in view of MSFN, so that crew procedure is standardized for all observations. This also assures that the sighting data is not lost due to downlink problems such as high-bit error rates at lunar distance.

Using the same four landmarks, an example of the MSFN evaluation could consist of determining orbits using MSFN data and comparing the computed optics observation with the actual observation. Since the landmark will not move, the optics observation residuals will show the divergence of the MSFN solutions. Various combinations of the optics observations can be used for the evaluation.

2.4 PHOTOGRAPHY

The darkside photography will be accomplished by the commander (CDR) on the last half of rev 8. The first half of rev 9 is devoted to photography to obtain the following photos:

a) Convergent stereo Hasselblad

b) Horizon - Hasselblad

c) Terminator

These photographic requirements are further defined in Reference 4.

2.5 PRE-TEI

The darkside pass of rev 9 is a crew eat period. Pre-TEI system checks and TEI preparation begin in rev 9 (approximately at TEI - 3 hours). This preparation consists of two P27 CMC updates and two P52 inertial measuring unit (IMU) realignments in addition to the P30 and P40 activity. Reference 2 contains the techniques description for the TEI burn planned for the end of rev 10.

3. MSFN TRACKING

Based on the SC attitude required to accomplish the photographic and landmark sighting objectives, the availability of the SC high-gain or omnidirectional (omni) antennas shown in Figure 2 has been established. The high-gain antenna is usable from acquisition of signal (AOS) to loss of signal (LOS) on revs 1, 2, 3, 9, and 10. On revs 4 through 8, the high-gain antenna is usable from the morning terminator (approximately) to LOS. During the early portion of these orbits, the SC is in landmark tracking attitudes; thus the high-gain antenna is not visible from earth. The omni antennas are available from AOS to LOS on all revs.

4. IMU ALIGNMENTS (P52)

Fine IMU alignments to the lunar orbit REFSMMAT uplinked by MCC-H will be performed on each orbit using P52. The nominal REFSMMAT is defined such that a 0-0-0 (roll, pitch, yaw) flight direction attitude indicator reading would result for a horizontal, in-plane, heads up, posigrade LOI-2 burn. This is the same REFSMMAT to be used for LOI-1, LOI-2, and TEI. These alignments will be performed after the SC has passed in front of the moon but prior to MSFN LOS. The automatic star selection and automatic optics positioning capability of the alignment programs will be used for each alignment. These successive alignments, placed as close as practical to the psuedo landing site landmark observation, will be used to perform drift checks and will enable postflight compensation of IMU drift effects on the sighting data. Following the P52 alignments, the stabilization and control system (SCS) will be aligned to the IMU.

5. UPLINKS, DOWNLINKS, AND VOICE (PAD) DATA

State vectors to provide the block data reference for TEI, in the event an abort is required, will be uplinked by MCC-H for every rev except after LOI-1 and LOI-2. For these two cases the CMC navigated state vector is assumed to be the best vector available at the time. (These CMC vectors will be evaluated by Data Select in real time as tracking data is obtained.) The uplinked state vectors will be based on tracking data obtained during the previous orbit and the vectors will be time tagged for approximately 3 hours later (1-1/2 revs). These vectors will be loaded in the CMC LM slots only rather than in both CSM and LM slots. The load is accomplished in less time with this procedure. (Three minutes are required to load a vector into either CMC slot.) If the uplinked vector is needed for an abort, the crew will perform the 4 DSKY entries required to transfer the vector from the LM slots to the CMC slots (UNZAP). The P27 uplinks will occur after passing the morning terminator but prior to the P52 alignments. Figure 2 shows the approximate location of the SC for the selection of these programs.

Associated with these state vectors is the block data sent up every rev to provide the TEI maneuver data. Tables 1 and 2 show the typical abort pad format and data transmitted each rev, respectively. The ground does not uplink abort maneuver data to the CMC for P30. Target ΔV data is loaded into the CMC only for planned maneuvers (LOI, TEI).

The state vectors for the planned maneuvers (LOI-1, LOI-2, and TEI) will be uplinked into both the CMC and LM slots. This is a safeguard in the event only the LM slot is loaded and the crew does not UNZAP the LM vector. After these planned maneuvers the integrated CSM vector will be transferred to the LM slots (ZAP).

To assist the crew with the landmark sightings, the estimated ground elapsed time of closest approach to the first identification point (IP) associated with the landmarks will be sent by the ground. Ground elapsed time will be provided for the closest approach to the unknown landmark IP's prior to the first time they are to be tracked and for the closest approach to the pseudo landing site landmark IP prior to each time it is to be tracked.

In addition to the standard downlist, downlinks are planned to dump the onboard tape recorded data as shown in the following table. The rev number in this table is the rev when the data will be transmitted.

DOWNLINKS

Data	Rev
LOI-1 burn data	1
LOI-2	3
TV	1 & 2
Landmark tracking data taken prior to AOS	4 through 8

At lunar distance, a tape dump over the downlink results in a random error of one bit per thousand. To get around this problem the tape will be dumped at least three times. When the downlink is used to transmit tape data to a site using an 85-foot antenna, voice communications can be maintained with the spacecraft. It is questionable that any other simultaneous downlink USB capability will exist for this case.

The go/no-go decision to continue lunar orbit or to perform the TEI maneuver will be made by MCC-H prior to LOS on each rev and will be voiced to the crew.

6. CONTINGENCY SITUATIONS

This section discusses some of the contingency situations that might occur in lunar orbit.

a) Onboard Tape Recorder Dump

At lunar distance, the onboard tape recorder can be dumped using the high-gain antenna only. If the high-gain antenna is operable in lunar orbit, the tape recorder will be used continuously and dumped once each rev as previously described. If the high gain is not usable, the following data will be recorded and saved until it can be transmitted via the omni antenna.

1) LOI-1, LOI-2, and TEI burn data recorded at high-bit rate. Fifteen minutes of the tape is allotted for this data. This time includes a few minutes for post-burn data for system evaluation.

2) The landmark sighting marks will be recorded at low-bit rate. These observations will require 12 minutes of tape.

3) Other items to be recorded are to be determined.

b) Landmark Sightings

The requirement of psuedo landing site landmark observations in four successive orbits must be satisfied. Therefore, in the event the landmark sightings scheduled for the fifth rev cannot be made due to poor lighting (or whatever), the sightings will be continued into the ninth rev and conflicting photography will be deleted.

c) Aborts

The detection of abort situations and the resulting action required is discussed in Reference 3.

Table 1. Typical Abort Maneuver Message Pad

MANEUVER													
												PURPOSE	
		/						/				PROP/GUID	
+	0	0				+	0	0				HRS GETI	N33
+	0	0	0			+	0	0	0			MIN	
+	0					+	0					SEC	
												ΔV_X	N81
												ΔV_Y	
												ΔV_Z	
+						+	3	5	1	8	9	ΔV_T	
X	X	X	:			X	X	X	:			BT	
X						X						ΔVC	
+						+						H_A	N42
												H_P	
X	X	X				X	X	X				R	
X	X	X				X	X	X				P	
X	X	X				X	X	X				Y	
+						+						WT	N47
	0	0					0	0				P_{TRIM}	N48
	0	0					0	0				Y_{TRIM}	
X	X	X	X			X	X	X	X			SXTS	
X	X					X	X					SFT	
X	X	X				X	X	X				TRN	
X	X	X				X	X	X				BSS	
X	X					X	X					SPA	
X	X	X				X	X	X				SXP	
	0						0					LAT	N61
												LONG	
+						+						RTGO	N63
+						+						VIO	
		:	:					:	:			GET .05G	
X	X	X	X			X	X	X	X			CNST G	

Table 1. Notes

- PURPOSE is the name of the maneuver (e.g., 90-minute or 4-hour abort)
- PROP/GUID is propulsion and guidance selected (SPS/P30)
- GETI is the time of ignition
- ΔV_x, ΔV_y, ΔV_z are the P30 velocity to the gained components in local vertical coordinates (fps)
- ΔVT is the total inertial velocity impulse (fps)
- BT is the burn time (min:sec)
- ΔVC is the EMS ΔV counter input
- H_A, H_p are the altitude of apogee and perigee, respectively above launch pad radius (n mi)
- R, P, Y are the IMU gimbal angles at the time of ignition for the abort maneuver (deg)
- WT is the CSM weight (lb)
- P_{TRIM} and Y_{TRIM} are respectively the pitch and yaw trim SPS gimbal angles (deg)
- SXTS is the sextant star to be used for the abort ignition attitude check
- SFT is the sextant shaft angle for the SXTS (deg)
- TRN is the sextant trunnion angle for the SXTS (deg)
- BSS is the boresight star for an ignition attitude check using the COAS (as required)
- SPA is the BSS pitch angle (COAS) (as required) (deg)
- SXP is the BSS X position (COAS) (as required) (deg)
- LAT and LONG are, respectively, the latitude and longitude of the resultant landing point following the abort maneuver (deg)
- RTGO is the range to go for the entry maneuver (EMS) (n mi)
- VIO is the EMS inertial velocity for the entry maneuver (fps)
- GET .05 g is the estimated ground elapsed time to the 0.05 g level of acceleration for the entry maneuver (hr:min:sec)
- CNST G is the value of g to be used for the backup entry technique (fps^2)

The last six items of the maneuver PAD are esentially an abbreviated entry PAD.

Table 2. Block Data Transmitted

Time Data Transmitted	Block Burn Data (TEI-x = TEI Performed at End of Revolution x)	Remarks
Pre-LOI-1	a) TEI-1	Assumes LOI-1 executed
	b) TEI-2	Assumes LOI-1 executed
	c) MCC 5	Assumes no LOI-1 executed, ΔV for return to CLA, perhaps fast return
Rev 1 (~LOI-1+1hour)	a) TEI-1	TEI-1 ΔV updated based on GMS TM indication of LOI-1, ΔV
	b) TEI-2	Updated based on GMS vector
Rev 2 (~LOI-1+3 hour)	a) TEI-3	Assumes LOI-2 accomplished
	b) TEI-3*	Assumes LOI-2 not performed
Rev 3 (~LOI-2+1 hour)	a) TEI-3	Updated based on GNCS vector
	b) TEI-4	Based on same GNCS vector
Revs 4 through 10	a) TEI-5 through TEI-10	One per rev based on MSFN vector

*Sent up in the event of total communications failure prior to LOI-2, in which case LOI-2 is not performed on the next rev.

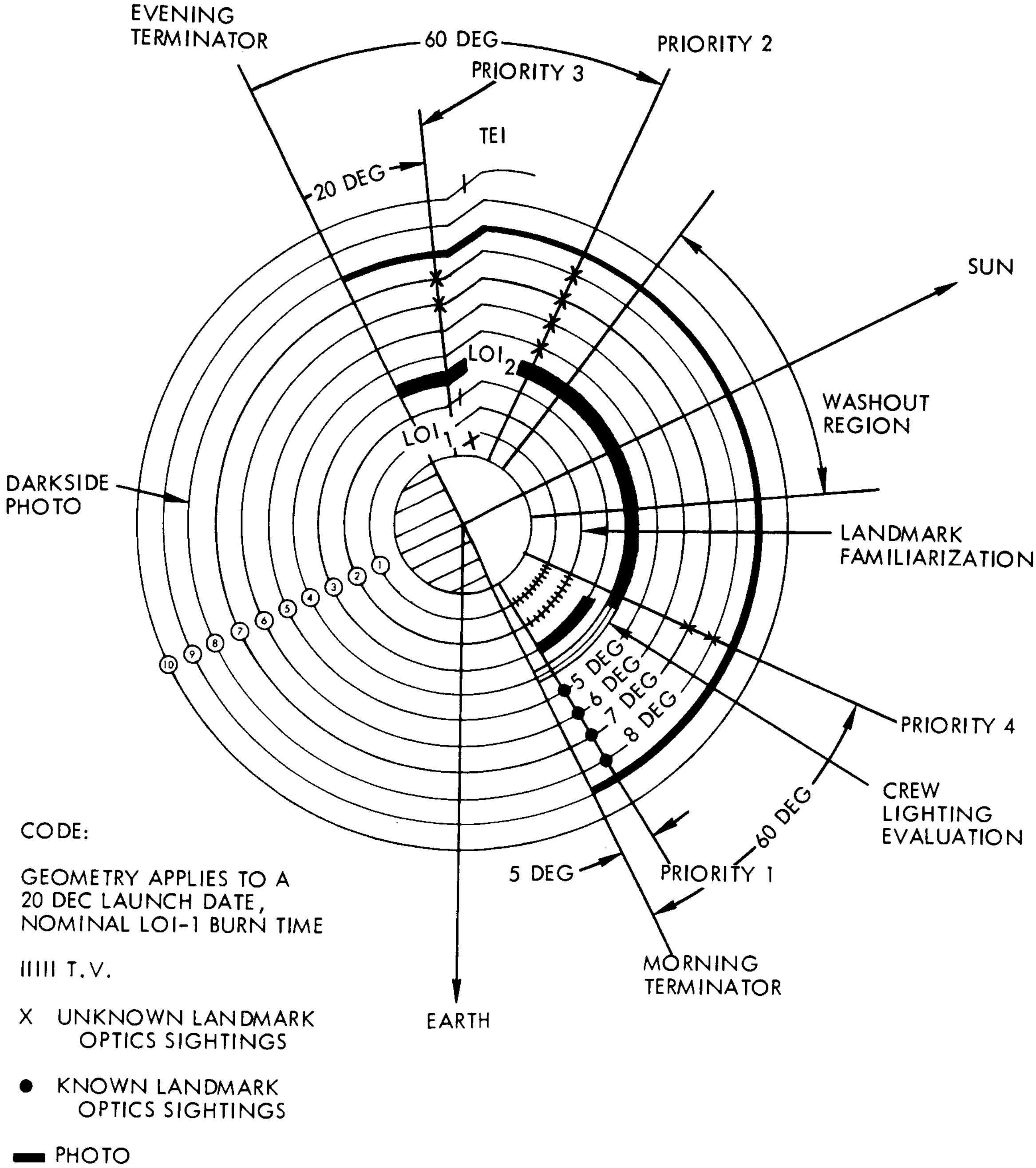
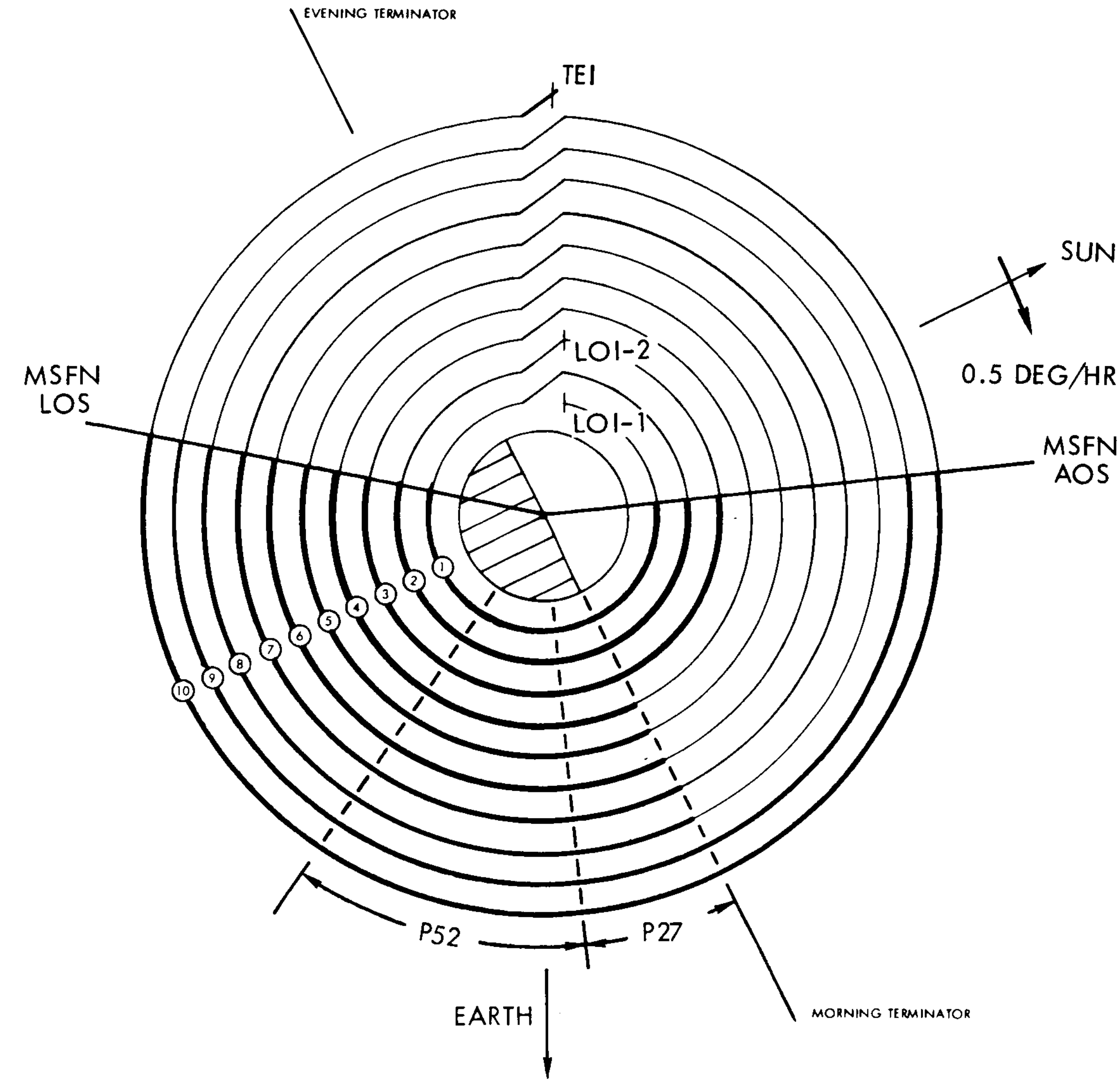


Figure 1. C-prime Lunar Orbit Activity



NOTE: GEOMETRY SHOWN FOR 20 DECEMBER LAUNCH DATE, NOMINAL LOI-1 BURN TIME.

— HIGH GAIN COVERAGE (OMNI USABLE FROM AOS TO LOS)

Figure 2. MSFN Lunar Orbit Coverage

REFERENCES

1. J. N. Dashiell, "Apollo Mission Techniques, Mission C-prime Lunar (Alternate 1) Translunar Midcourse Corrections and Lunar Orbit Insertion," MSC Internal Note No. S-PA-8M-030, November 13, 1968.

2. C. R. Belton, "Apollo Mission Techniques, Mission C-prime Lunar (Alternate 1) Transearth Injection, Midcourse Corrections and Entry," MSC Internal Note No. S-PA-8T-028, October 28, 1968.

3. C. R. Skillern, "Apollo Mission Techniques, C-prime Lunar (Alternate 1) Contingency Procedures," MSC Internal Note No. S-PA-8M-031, October 29, 1968.

4. J. G. Zarcaro, "Mission Requirements, C′ Type Mission (Lunar Orbit)," SPD8-R-027, October 22, 1968.